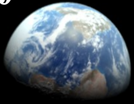
Deep Space Gateway:
Enabling Missions to the Lunar Surface



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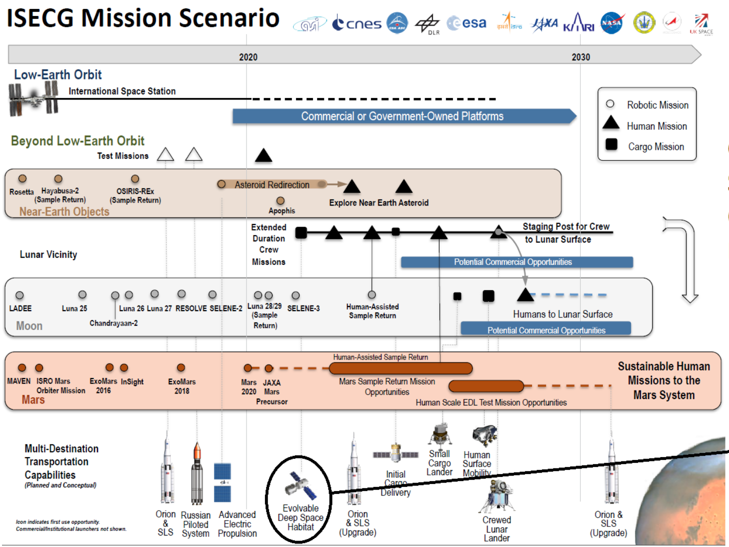
NASA

November 29th, 2017

Global Exploration Roadmap (GER) Mission Scenario



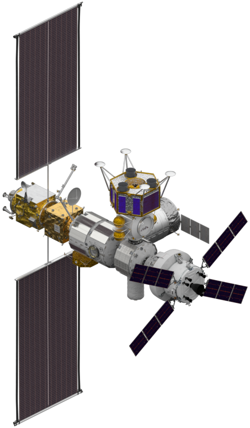
GER Version 2 Scenario Chart Published in 2013

Deep Space Gateway

Advantages of a Deep Space Gateway

What are the advantages of a Deep Space Gateway for staging human missions to the lunar surface?

1. The human lunar lander can be made **reusable**, shifting cost from recurring units to enabling a market for in-space refueling
2. By maintaining infrastructure in a libration point orbit, opportunities are created for **both large and small launchers** to contribute
3. Risk is decreased by making the Gateway available as a crew **safe haven** in a surface abort scenario

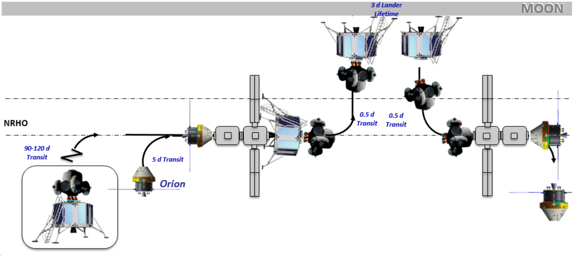


A conceptual deep space gateway construct showing a trade space of elements. The lander shown here represents a key component of the Global Exploration Roadmap's lunar surface mission scenario.

Deep Space Gateway Functionality for Lunar Surface missions

What specific functions could the Gateway serve in a lunar surface architecture?

1. Storage and refueling of a reusable ascent module
2. Safe haven for crew aborting from the surface
3. Communications relay to Earth from the lunar far side
4. Teleoperations of robotic systems (on the far side)
5. Access to medical and exercise equipment for reconditioning.
6. Act as a hub for refueling spacecraft consumables.



Gateway Staging Orbit Trade

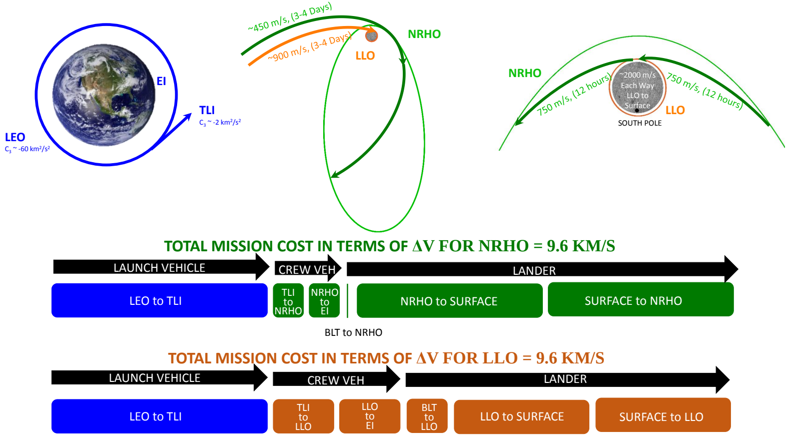
Selection of the Gateway orbit directly impacts lunar lander design.

		Low Lunar Orbit	NRHO	L_2 Halo	DRO
Habitat	Thermal	Lunar surface reflection results in higher rejection requirement	Deep space Equivalent	Deep space equivalent	Deep space Equivalent
	Orbit Maintenance	Frequent perilune adjust (~75 m/s per year)/more demand on attitude control	Frequent orbit corrections but smaller (<10m/s per year)/less demand on attitude control	Frequent orbit corrections but smaller (<50 m/s per year*)/less demand on attitude control	Minimal/least demand on attitude control
	Communication	Up to ~50 % lunar occultation	No occultation	No occultation	Infrequent occultation
	Power	Frequent Eclipses	Infrequent and avoidable short eclipses	Infrequent eclipses	Unavoidable several hour eclipses
Orion	Access / Return	Insufficient	Within Capability	Within Capability	Within Capability
	Early Return	Insufficient	Does not always meet 144 hr. return requirement	Does not always meet 144 hr. return requirement	Does not always meet 144 hr. return requirement
Surface Access	2 Crew Lander	~24 t Storable	~34 t Storable	~40 t Descent: LOX/CH4 Ascent: Storable	~48 t Storable
	4 Crew Lander	~30 t Storable	~39 t Descent: LOX/CH4 Ascent: Storable	> 50 t Descent: LOX/CH4 Ascent: Storable	> 50 t Descent: LOX/CH4 Ascent: Storable

The preferred Gateway orbit is known as the **Near Rectlinear Halo Orbit (NRHO)**. While no orbit is ideal for all performance metrics, the NRHO best fits the constrained attributes across all 3 elements of the architecture.

Note: Orion translation is limited to < 1000 m/s and SLS cargo to TLI maxes out at 40 tons.

Orbit Mechanics of Gateway Based Lunar Lander



*Note crew vehicle cost for LLO exceeds Orion current capability

**Note BLT (ballistic lunar transfer) to orbit is for lander delivery only

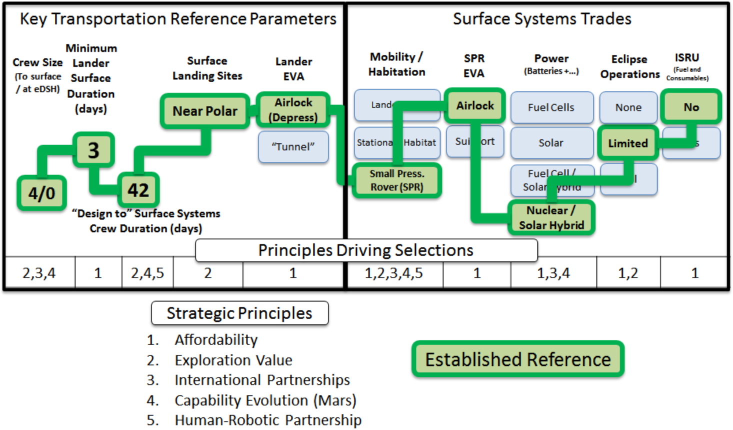
Selecting a higher orbit such as NRHO for the Gateway trades propellant required for the lunar surface from the crew vehicle (Orion) to the lander. The lander would be launched on its own SLS and would arrive on a slow transfer where it can save significant fuel.

Architecture Drivers as Defined by ISECG

The combined principles could be summarized as an endeavor to maximize partnership opportunities by prioritizing modular systems while at the same time minimizing cost and complexity, ultimately favoring minimum mass solutions.

1. GER derived strategic principles $\longrightarrow$ **Affordability, Exploration Value, International Partnerships, Capability Evolution, Human-Robotic Partnership**
2. GER derived goals and objectives $\longrightarrow$ **Series of missions, 4 crew and 28+ days on surface**
3. Capability based constraints as framed by international participants. $\longrightarrow$ **Currently featuring ESA, CSA, JAXA and NASA contributions**

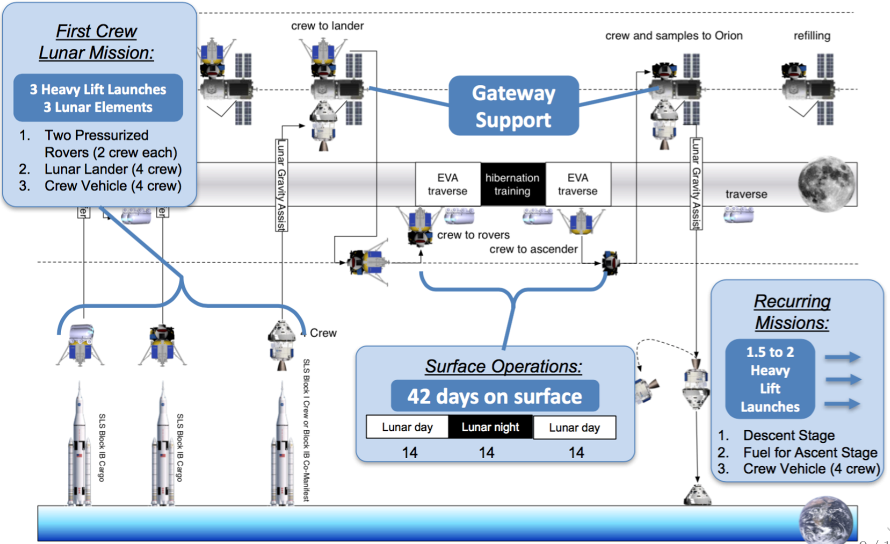
Final GER Trade Space



A completely mobile based system was selected as the preferred implementation for the crewed stays. Two pressurized rovers provide full habitation for 2 crew members each for 42 days (2 lunar days + 1 lunar night). **A mobile system maximizes landing site diversity while simultaenously minimizing surface infrastructure.**

Potential Design Reference Mission

Initial **3 Launch** scenario. Subsequent missions require **1.5 launches**.



Two Stage Lander

Reusable Ascent Module

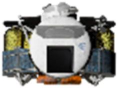
- Main function: deliver 4 crew safely to the lunar surface and back.
- 3-4 day lifetime capability required for abort modes
- Reduced pressurized volume to 10 m^3 to save mass
- Pump-fed storable fuel-based engines

LO_2/CH_4 **Descent Module**

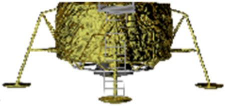
- LO_2/CH_4 was selected for the descent module for ISRU potential and increased performance
- Key features of descent module given below:

Item	Descent Module
Main Propellants	LO_2/CH_4
# Engines	3
Engine Thrust	>80 kN
Engine I_{sp}	370 s
RCS	40 x 220 N
Power	Solar Panels

AM
(ESA)
9.9 tons



DM
(JAXA)
25.1 tons



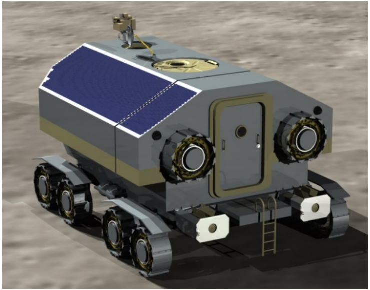
35.0 tons Total

Reusable Surface Rovers

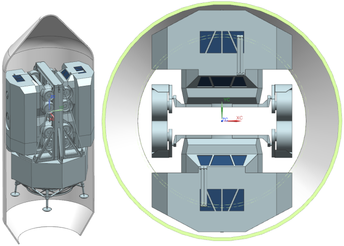
Pressurized Rover Characteristics

- 2 reusable rovers carry 2 crew members each
- Yearly missions will require small cargo resupply which could provided by commercial entities or copies of HERACLES
- Current design fits 2 rovers atop a descent module in launch vehicle shroud
- Unique hybrid power system includes deployable solar panels, radioisotope power and a rechargeable stored power source

Notional Rover Design

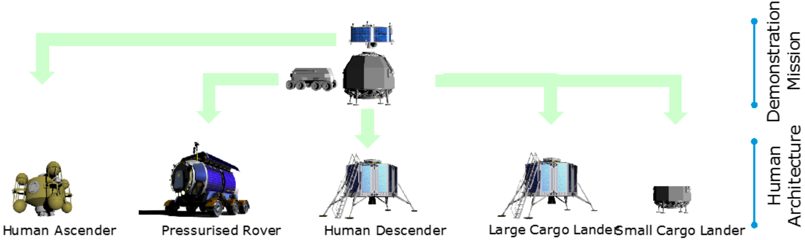


Notional Launch Configuration



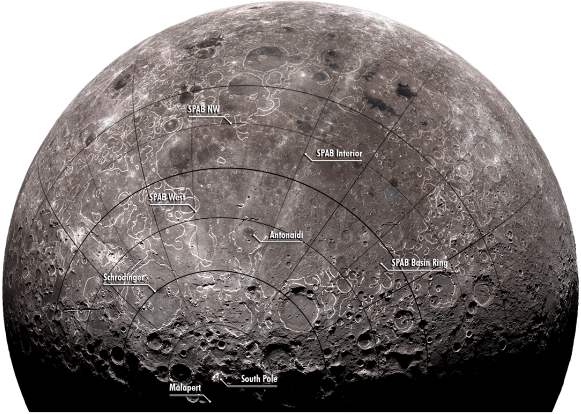
Element Co-Development

Relationship between demonstrator and human elements



(ESA) (NASA/CSA) (JAXA) (JAXA) (JAXA)

Potential Lunar South Polar Landing Sites



Regions of Interest in South Pole Aitken Basin

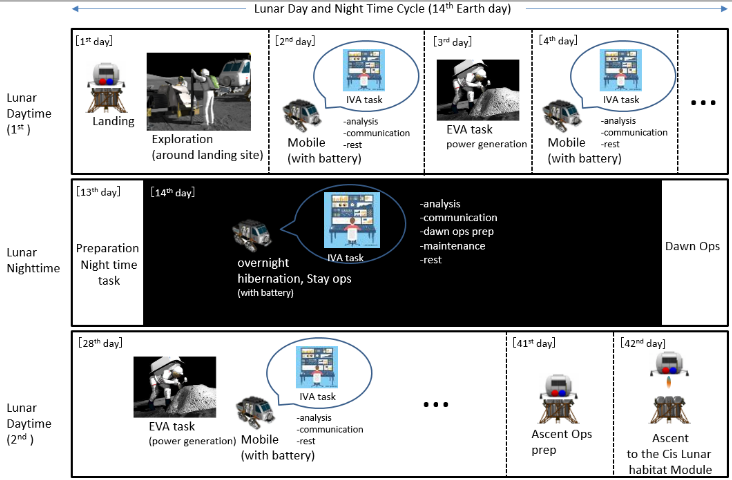
VALUE OF LUNAR SCIENCE

The Moon has experienced many of the geologic processes that have shaped the terrestrial planets in our Solar System. Collecting the right samples on the Moon will improve our understanding of the origin of the Earth-Moon system, and of terrestrial planets in general. The lunar soil and subsurface provide a historical repository of the Solar System's evolution. Human presence could permit the emplacement of delicate surface instrumentation on the lunar Far side, such as sensitive radio telescopes or gravity wave detectors.

Surface Exploration Themes and Corresponding Objectives

Theme	Objective
Geological Features	Geological Exploration as wide area of SPAB
Water or Ice	Lunar Water/Ice or Volatile component exploration for ISRU
Observation	Moonquake observation. Astronomical Observatory on lunar surface.

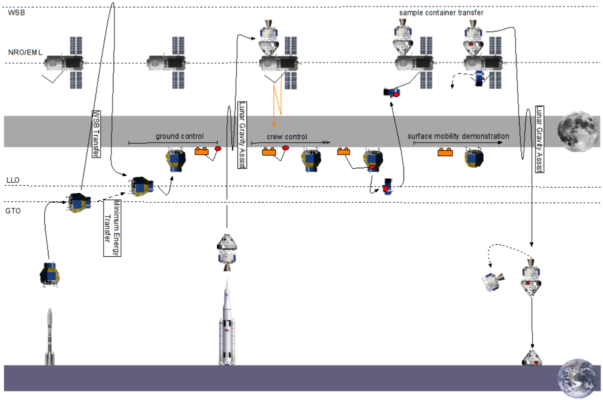
Crew Concept of Operations



An example breakdown of a 42 day surface mission is shown. During the 14 days of continuous daylight available at the beginning and end of the mission, crews from each of the two rovers can alternate EVA days to enable daily exploration.

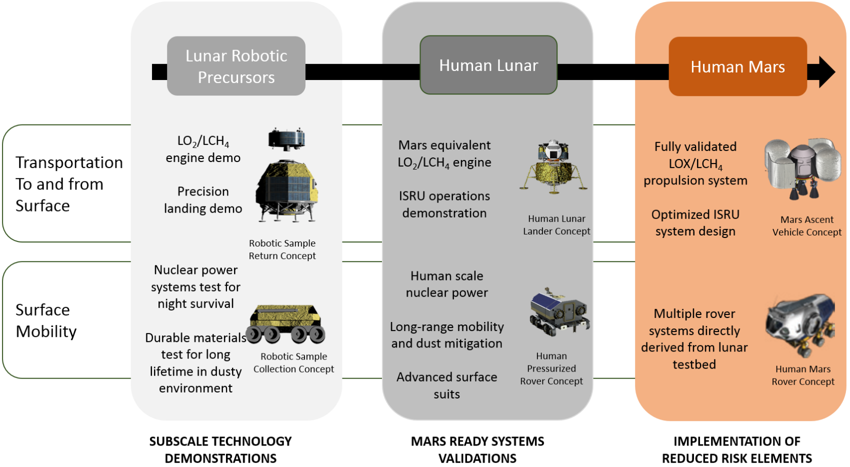
Sub-Scale Demonstrator Mission

- Demonstrator mission scenario now in phase-0 level by CSA, ESA, and JAXA
- Once landed, surface rover will collect up to 15 kg of samples from previously unexplored regions of the Moon.
- Deep Space Gateway would be involved in tele-operation of rover as well as the lunar sample transfer to crew vehicle for Earth return



To the Moon and on to Mars

Lunar Surface Systems that Directly Feed Forward to Mars Surface Systems



Gateway Enabled Human Surface Summary

- Lunar surface concept is logical combination of:
  - **Planned** components (SLS and Orion)
  - **Conceptual** components (Gateway)
  - **New** components (Human Lander and Pressurized Rovers)

- Key characteristics of international concept for lunar return include:
  - Rover and partial lander **reusability** to reduce number of heavy lift launches
  - Reliance on **Gateway** for refueling and staging
  - Opportunities for new lunar **science** including volatiles
  - **Limited** surface campaign to reduce number of new development programs and ongoing costs with opportunities to pivot to Mars

- Limited campaign lunar exploration elements are designed to have significant overlapping capability relevant to human Mars exploration elements and functions including:
  - *Lunar Lander* $\longrightarrow$ *Mars Ascent Vehicle*
  - *Reusable Lunar Rover* $\longrightarrow$ *Mars Pressurized Rover*
  - *Lunar LOX/CH4 Propulsion* $\longrightarrow$ *Mars LOX/CH4 Propulsion*
  - *Lunar Surface Nuclear Power* $\longrightarrow$ *Mars Surface Nuclear Power*

http://www.globalspaceexploration.org

ISECG

International Space Exploration Coordination Group